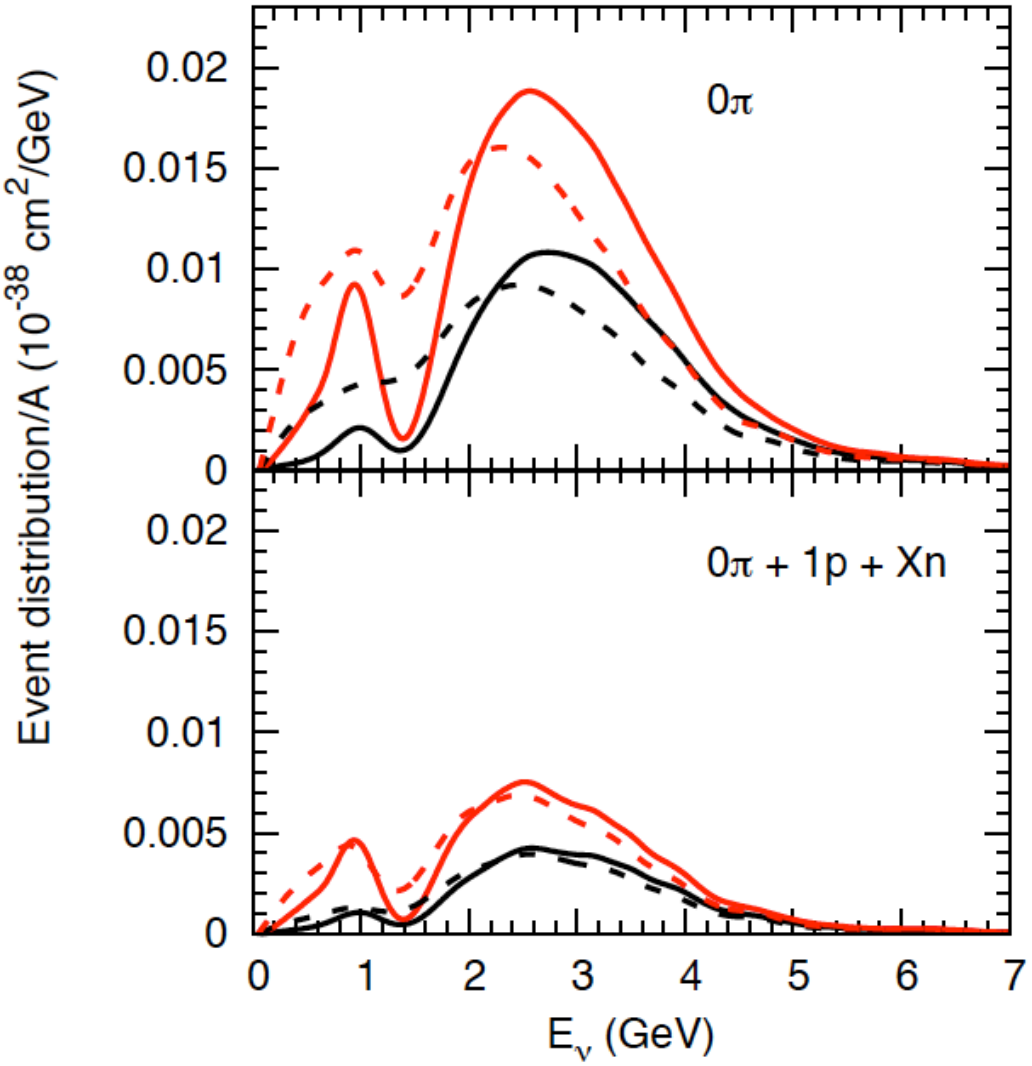
The Challenge!

- E_ν via QE hypothesis
- Red true $\delta = +\pi/2$
- Red reconstructed
- Black true $\delta = -\pi/2$
- Black reconstructed
- **GiBUU transport model**
- Excellent – we know how to unfold back to the "true" distributions, right?



Neutrino Interactions Working Group

G. Garvey and J.G. Morfín

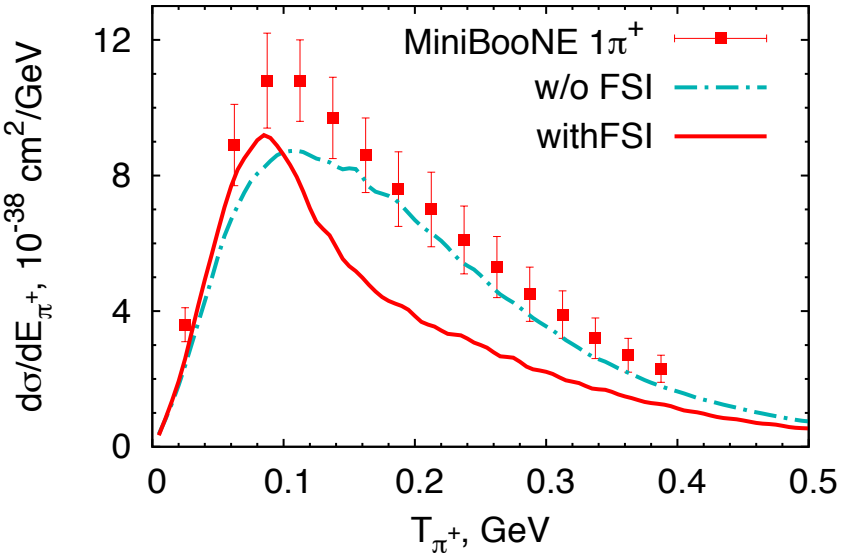
8:30-8:40	**Introduction (Garvey-Morfin)**
8:40-9:10	**Nuclei-Nuclear QE and Resonance Formation, – (Emphasis on Ar) (Joe Carlson)**
9:10-9:35	**Relativity and FSI (Bill Donnelly)**
9:35-10:05	**Current Experimental Results and generator predictions (Phil Rodrigues)**
10:05-10:25	**Discussion with coffee: nuclear models and current data**
10:25-11:05	**Event Generators: initial states and FSI (Steve Dytman)**
11:05-11:35	**Future LAr neutrino interaction program - (Flavio Cavanna)**
11:35-12:05	**Future Fine-grained neutrino interaction program (Jeff Nelson)**
12:05-12:30	**Discussion and Bullet Formulation**

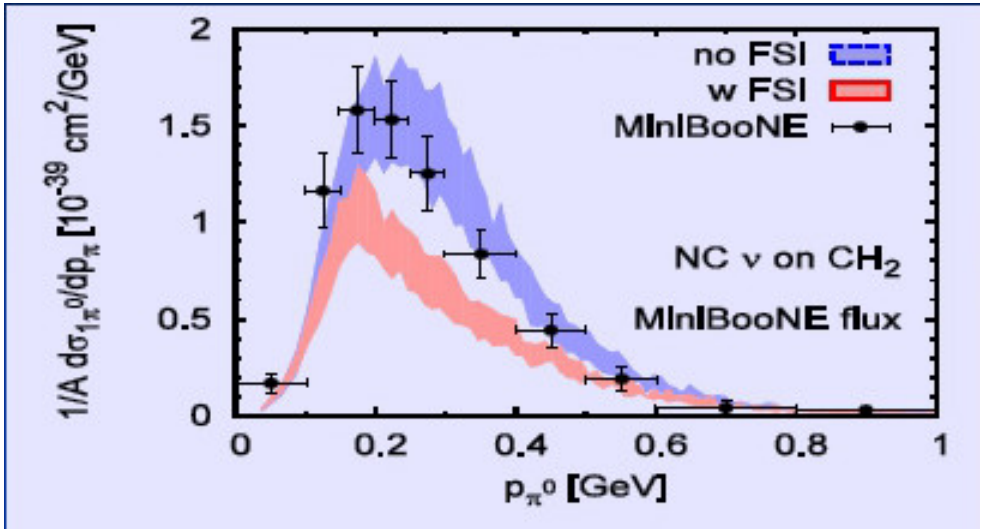
Well …. maybe not!

Phil Rodrigues and Steve Dytman

- GiBUU prediction for MiniBooNE π^+ and π^0 distributions
- Predictions without Final State Interactions fit best!

GiBUU MiniBooNE CC1π^+





- **No single model in current event generators (GiBUU, GENIE, nuWRO, NEUT) can fit the current data set. Address the situation**

Models of the Nucleus

Joe Carlson and Bill Donnelly

- There are already models of the nucleus that give far better agreement for inclusive reactions than what currently exists in event generators.
- Getting these models installed in the generators is a demanding effort requiring significant community effort.
- Any model that does not succeed for electron scattering is very unlikely to be valid for neutrino reactions.
- Relativistic effects from kinematics and boost factors are essential for NuMI and LBNF experiments.
- For inclusive reactions FSI in both initial and final states are significant and naïve models such as the RFG fail at the 25% level or so to reproduce the data.
- MEC effects are significant (and should be modeled relativistically).
- While the models discussed here are good for inclusive scattering, they are not suited to even semi-inclusive scattering and will require a large nuclear phenomenological effort.

Future Neutrino Interaction Program

Flavio Cavanna and Jeff Nelson

- A rich program of neutrino interaction experiments in the near and intermediate future:
- LAr Program:
  - Highest resolution & Extra Large Statistics LArTPC Data *in the few hundred MeV to few GeV energy range, using the Booster & the NuMI beams* are expected from the "*present*" and "*Intermediate*" LAr neutrino program at FNAL ***(MicroBooNE, LAr-ND, ICARUS-T600 and Captain-SBN/Captain-Minerva, respectively)***
- Sampling Detector Program:
  - MINERvA ME Physics Program
  - NOvA Near Detector Program
  - T2K
  - CAPTAIN-MINERvA
  - nuPRISM
  - ANNIE

The View From Oscillation Experiments

Elizabeth Worcester

- Cross-section and nuclear models: Beyond current uncertainties
  - Basic strategy is to compare observables among alternative cross- section and nuclear-interaction models in GENIE
  - Comparison with data (MINERvA, NOvA-ND, T2K-ND280, μBooNE, LAr1-ND, T600, ...)
  - Comparison with alternative generators (NuWro, GiBUU)

- **Requires support for and close collaboration among model builders, developers of event generators, cross-section experiments, and ELBNF.**

Current Summary Bullets

- The Neutrino-Nucleus Interaction is the least understood component of a detector's response to neutrinos**.**
- Improvements of nuclear models by nuclear theorists are essential. This can most efficiently be accomplished with additional financial support of NP theorists. Rapidly incorporating these improvements in event generators is equally important
- The current experimental neutrino interaction program (MINERvA, NOvA-ND, MicroBooNE, T2K Near Detector) continues to provide important data and should be supported to its conclusion. This includes efforts to improve the precision with which the neutrino flux is known.
- The critical role of neutrino nucleus event generators needs to be emphasized and more community resources devoted to keeping them widely available, accurate, transparent, and current. It is critical to benchmark the generators against both accelerator-based neutrino-nucleus interaction measurements and, via a collaborative HEP and NP effort, electron-nucleus interaction measurements. For example, expanded use of the existing Jefferson Laboratory data set could bring significant insight.

Current Summary Bullets

- Future neutrino interaction measurements are needed to extend the current program of GeV-scale neutrino interactions. The feasibility of a high-statistics deuterium experiment should be considered. Current and future long-and-short-baseline neutrino oscillation programs should evaluate what additional neutrino nucleus interaction data is required to meet their ambitious goals and support experiments that provide this data

- Measurements and theoretical work are needed also to characterize neutrino interactions in the low energy regime (<100 MeV). This regime is especially relevant for core-collapse supernova neutrinos, and understanding is essential for development of future underground detectors. This is also an area for which collaboration with NP will bring in critical expertise.

Emphasis on Collaboration between NP Theorists, Event Generator Collaborators and Neutrino Experimentalists

NuSTEC

- **Generators**: Coordinate theorist-experimentalist collaborative efforts to improve generator(s).
- **Global Fits**: Combine results from multiple experiments – not only neutrino - to compare/adjust with a theory/model framework.
- **Training**: Organize/Run a a generator and neutrino-nucleus scattering physics Training Program
  - Generator School: May 2014 at Liverpool
  - Nuclear Physics Training: Fermilab October 2014
- **Workshops**: Organize Community-wide Workshops when needed.

Attempt to form an NP theorist - HEP experimentalist collaborative effort to get improved models in generators

- A program of research improving the modeling of neutrino-nucleus scattering using quantum Monte Carlo (QMC) techniques by a collaboration of NP-theorists and HEP neutrino experimentalists with the practical goal of producing an accurate description of neutrino-nucleus interactions in neutrino event generators.
- Request support for postDocs to work with the theorists – FOA?

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